

1

(a) State which type of radiation, α , β or γ ,

(i) produces the greatest number of ion pairs per mm in air,

(ii) could be used to test for cracks in metal pipes.

(2)

(b) Specific radioisotope sources are chosen for tracing the passage of particular substances through the human body.

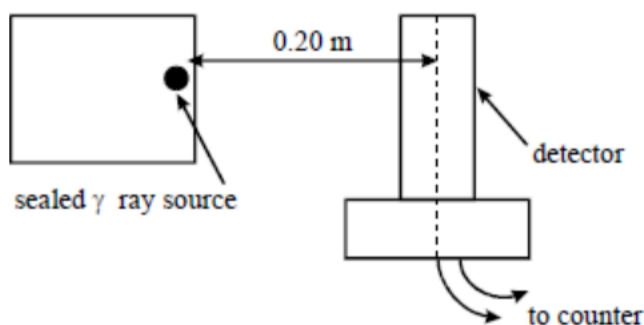
(i) Why is a γ emitting source commonly used?

(ii) State why the source should **not** have a very short half-life.

(iii) State why the source should **not** have a very long half-life.

(3)

(c) A detector, placed 0.20 m from a sealed γ ray source, receives a mean count rate of 2550 counts per minute. The experimental arrangement is shown in the diagram below. The mean background radiation is measured as 50 counts per minute.



Calculate the least distance between the source and the detector if the count rate is not to exceed 6000 counts per minute.

(5)

(Total 10 marks)

2

A radioactive nucleus decays with the emission of an alpha particle and a gamma-ray photon.

- (a) Describe the changes that occur in the proton number and the nucleon number of the nucleus.

proton number _____

nucleon number _____

(2)

- (b) Comment on the relative penetrating powers of the two types of ionizing radiation.

(1)

- (c) Gamma rays from a point source are travelling towards a detector. The distance from the source to the detector is changed from 1.0 m to 3.0 m.

Calculate

intensity of radiation at 3.0 m

intensity of radiation at 1.0 m

answer _____

(2)

(Total 5 marks)

3

A student has access to a radioactive source that decays by emitting alpha, beta and gamma radiation. The student wishes to investigate whether the count rate due to the gamma radiation varies with distance from the source according to an inverse square law and sets up the source and detector as shown in **Figure 1**.



- (a) State and explain how the student can ensure that only gamma radiation is detected during the investigation.

(2)

- (b) The corrected count rate due to gamma radiation is 64 counts per second at a distance of 50 mm from the source. Assuming that an inverse square law is obeyed calculate the expected corrected count rate at a distance of 80 mm from the source.

Count rate at 80 mm _____

(2)

- (c) Using the data from part (b) sketch, on the axes in **Figure 2**, the graph the student would expect if an inverse square law were obeyed. The corrected count rate at 50 mm has been plotted already.

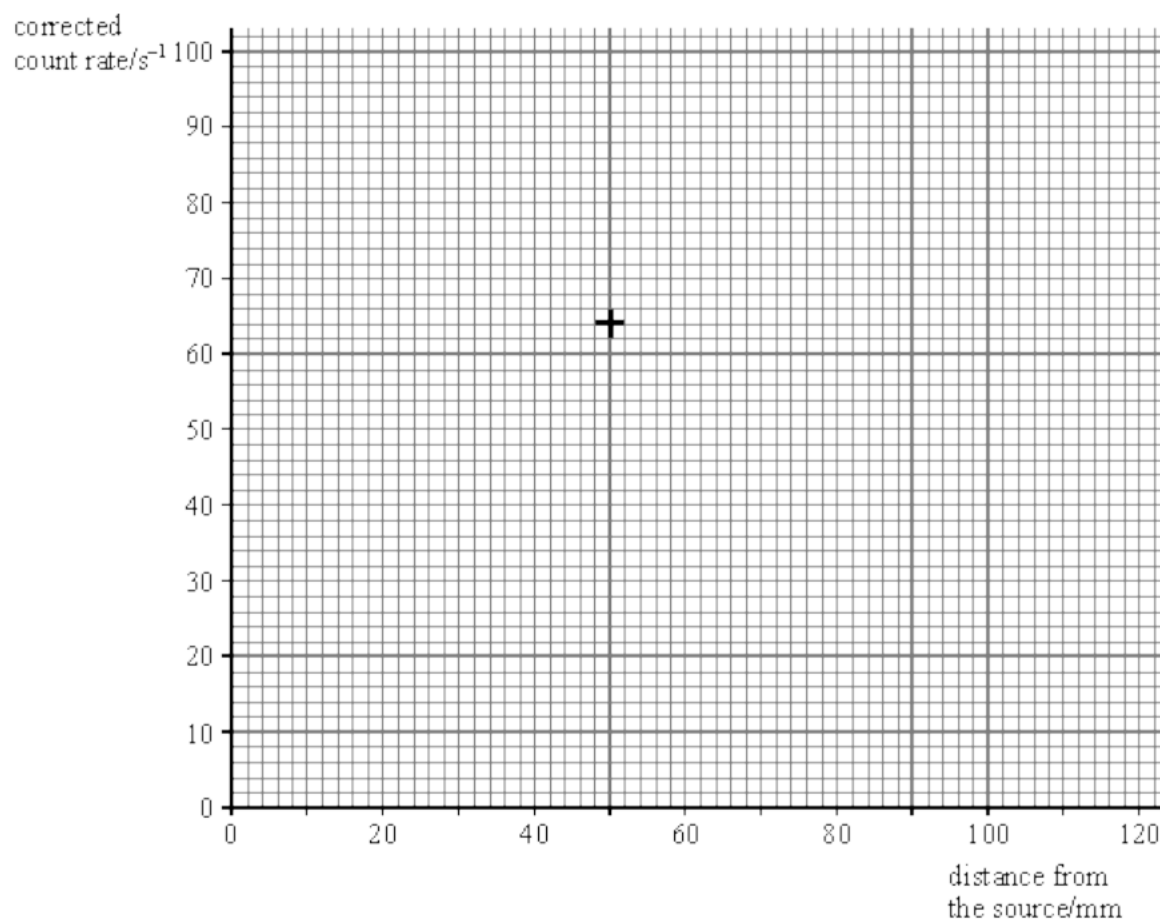


Figure 2

(2)

(Total 6 marks)

4

Potassium-42 decays with a half-life of 12 hours. When potassium-42 decays it emits β^- particles and gamma rays. One freshly prepared source has an activity of 3.0×10^7 Bq.

- (a) To determine the dose received by a scientist working with the source the number of gamma ray photons incident on each cm^2 of the body has to be known.

One in every five of the decaying nuclei produces a gamma ray photon. A scientist is initially working 1.50 m from the fresh source with no shielding. Show that at this time approximately 21 gamma ray photons per second are incident on each cm^2 of the scientist's body.

(2)

- (b) The scientist returns 6 hours later and works at the same distance from the source.

- (i) Calculate the new number of gamma ray photons incident per second on each cm^2 of the scientist's body.

(3)

- (ii) At what distance from the source could the scientist now work and receive the original dose of 21 photons per second per cm^2 .

(2)

- (c) Explain why it is not necessary to consider the beta particle emission when determining the dose of radiation the scientist receives.

(2)

(Total 9 marks)

Mark schemes

1	(a) (i) α (radiation) (1) (ii) γ (radiation) (1) (b) (i) the radiation needs to pass through the <u>body</u> (to be detected) (1) (ii) (otherwise) the activity of the source becomes too weak (during measurements) (1) (iii) the decaying source may remain in the body for a <u>long time</u> and could cause damage (1) [or the activity of the source will be low unless a large quantity is used ($T_{1/2} \propto 1/\lambda$)] (c) corrected count rate at 0.2 m (= 2550 - 50) = 2500 (c min⁻¹) (1) corrected count rate at least distance (= 6000 - 50) = 5950 (c min⁻¹) (1)	2
	<u>use</u> of $I = k \frac{I_0}{x^2}$ (or in the form $\frac{I_1}{I_2} = \left(\frac{x_2}{x_1}\right)^2$) (1) (allow C.E. for using uncorrected count rate) gives least distance = $0.20 \times \left(\frac{2500}{5950}\right)^{1/2}$ (1) least distance = 0.13 m (1)	3
		5 [10]
2	(a) (proton) down 2/-2 (nucleon) down 4/-4 (b) gamma greater, <i>must express comparison</i>, <i>don't allow simple list</i>	B1 B1 2 B1 1

- (c) use of inverse-square law

C1

$$\frac{1}{9} / 0.11$$

A1

2

[5]

3

- (a) place a sheet of aluminium/metal between source and detector

Sheet thickness stated 2 to 10 mm thick or several/a few mm thick **plus**

M1

only gamma radiation can pass through such a sheet or alpha and beta will be absorbed/stopped by the sheet

A1

2

- (b) count rate $\propto 1/r^2$ or evidence of $C_1/C_2 = r_2^2/r_1^2$

C1

25 counts per second (allow cps or s^{-1})
(Bq is a up)

A1

2

- (c) their value calculated in (b) plotted correctly and reasonable attempt to draw correct curvature

C1

Correct point (25 cps) plotted with correct curvature
(mark quality: must not flatten out or rise at end of their line for large distances)

A1

2

[6]

4

(a) number of gamma ray photons per sec = $\frac{3.0 \times 10^7}{5}$ (= 6.0×10^6)

B1

correct use of $4\pi r^2$; substitution of data

$$\frac{6.0 \times 10^6 \text{ or } 3.0 \times 10^7}{4 \times \pi \times 150^2} = 21.2$$

NB they may determine number per m^2 and divide by 10 000

B1

(b) (i) decay constant = $0.69 / 12 = 0.0575 \text{ h}^{-1}$ or 1.6×10^{-5}
(or time = .5 half life)

CI

$$\text{dose} = 21e^{-(6 \times 0.0575)}$$

$$\text{dose} = 21 / 20.5$$

CI

$$\text{or new (gamma) activity} = 6 \times 10^6 e^{-(6 \times 0.0575)}$$

$$\text{or new (total) activity} = 3 \times 10^7 e^{-(6 \times 0.0575)}$$

CI

15 (gamma rays per cm^2 per second) Condone 14.8 – 14.9
(no up)

AI

(ii) clear attempt to apply inverse square law

CI

$$1.3 \text{ (1.26) m}$$

AI

(c) beta particles are more heavily ionising than gamma radiation
or
loses energy rapidly by ionising the air / matter

BI

beta particle range / penetration (in air) is low

or

beta particle range

is about 30 cm

or

is less than 1.5 m

or

is much lower than gamma radiation

NB: mention of not able to penetrate skin or clothing is talk out

BI